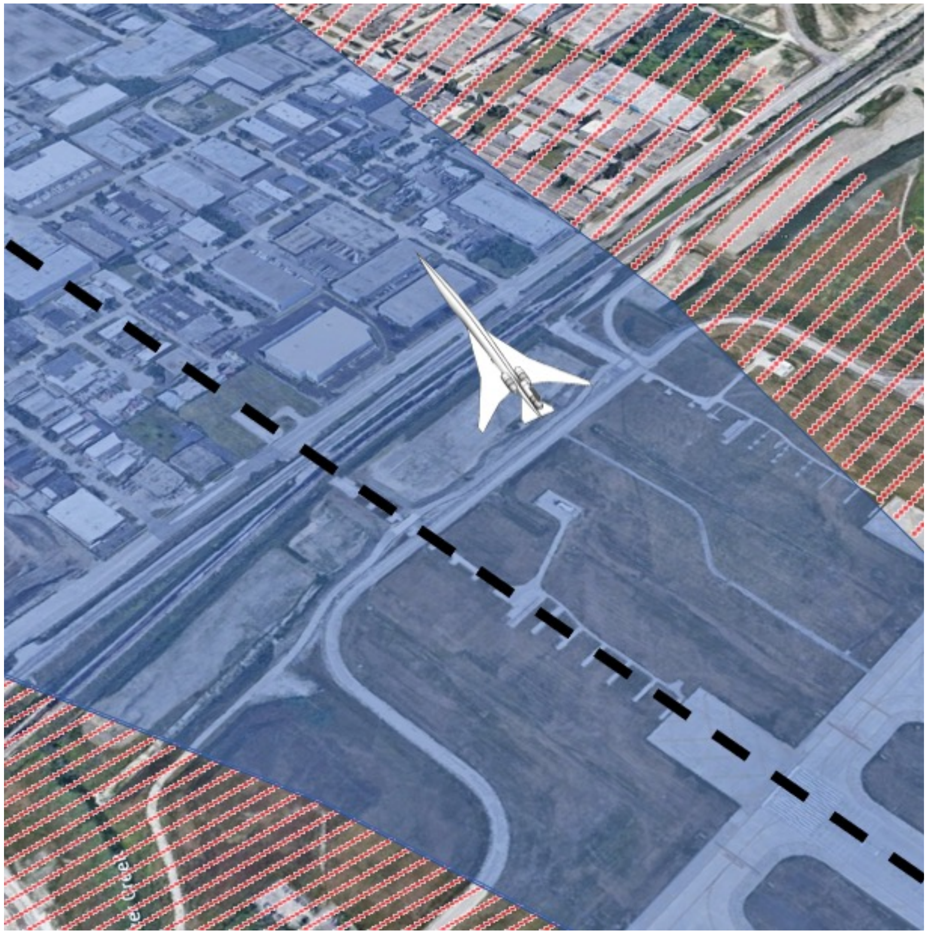
# Update on Prediction Uncertainty Reduction (PUR) Tech Challenge



*Commercial Supersonic Technology*
*NASA Acoustics Technical Working Group Meeting*
*12 April 2022*

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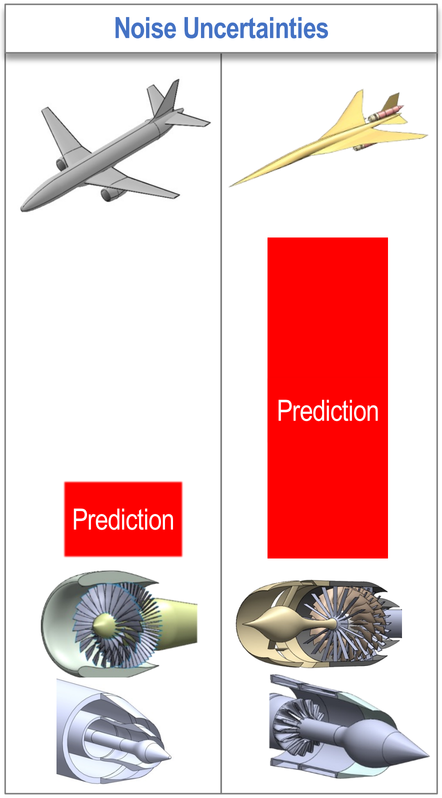
# Tech Challenge: Prediction Uncertainty Reduction (PUR)

- Uncertainty in prediction of LTO noise is primarily associated with **configuration differences** between conventional and supersonic aircraft.
- Empirical models not based on supersonic configurations.
- Tech Challenge approach
  – Obtain relevant inlet, fan, and nozzle designs from OEM input.
  – Use **physics-based simulations** (PBS) of supersonic aircraft to produce 'data'.
  – Allow empirical models to be modified for future studies by all parties.

First steps
- Create metrics for uncertainty assessment
- Baseline uncertainty of system tools for conventional vs supersonic aircraft
- Baseline uncertainty of physics-based simulations for fan and jet noise



# Uncertainty Propagation via Monte Carlo Simulation

## Deterministic model for total aircraft noise (ANOPP-based)…

Constant benchmark inputs $x$ for aircraft noise components

$x_1$
$x_2$
…
$x_n$

Model
$f(x_i)$

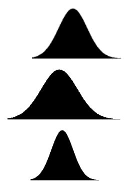
Benchmark EPNL results

$EPNL_{Lateral}$
$EPNL_{Flyover}$
$EPNL_{Approach}$
$EPNL_{Cumulative}$

## …becomes Stochastic model

Component uncertainties

Randomized inputs $x'_i$ for each aircraft noise component



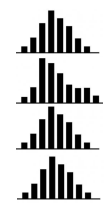
$x'_1$
$x'_2$
…
$x'_n$

Distributions reflect errors in model from poor fits to data and to design variables not in models.

Model
$f(x'_i)$

EPNL sensitivities

$EPNL_{Lateral}$
$EPNL_{Flyover}$
$EPNL_{Approach}$
$EPNL_{Cumulative}$



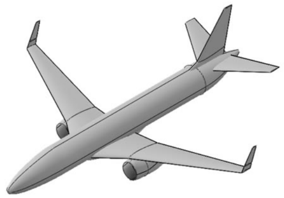
Histograms, “uncertainty” of EPNL.

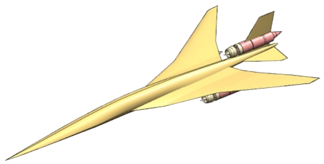
Aircraft uncertainties

# Baseline Uncertainty Assessment

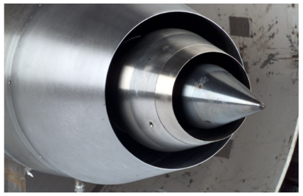
Jeff Berton, James Bridges, David Stephens

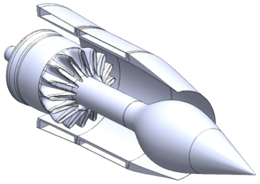
Obtaining component uncertainties for conventional and supersonic aircraft





| Conventional (737-800/CFM56-7B27) | | | | Supersonic (STCA 55t-U) | | | |
|---|---|---|---|---|---|---|---|
| Fan | | Jet | | Fan | | Jet | |
| ANOPP *HDM3* | GEHSF rig test | ANOPP *Stone2* | SFNT97 rig test | ANOPP *HDM3+4* | QSP (2-stage fan) rig test | ANOPP *SAE876* | GE11, Plug20 rig tests |





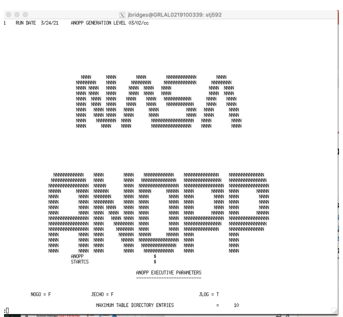
# Example: Baseline Uncertainty of Conventional Fan

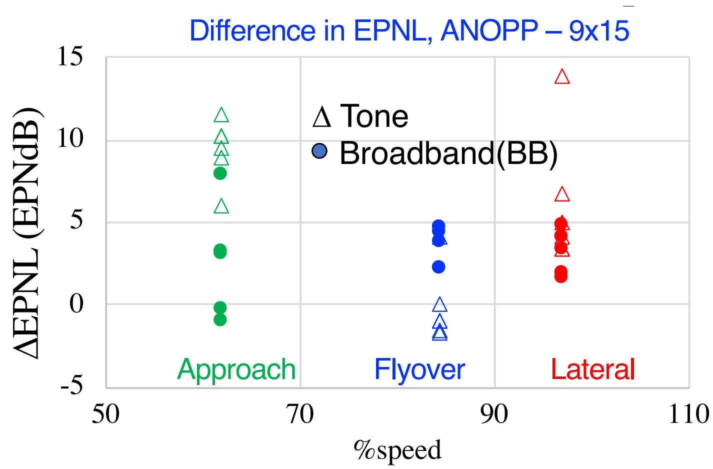
David Stephens, Jeff Berton

Discrepancies Δ2 == ANOPP predictions vs 9x15 rig data for 6 configurations, 3 speeds.
Compare component EPNL as numerically flown for each test point.
Summarize ΔEPNL by offset and standard deviation

Data from 9x15 LSWT

Predictions from ANOPP

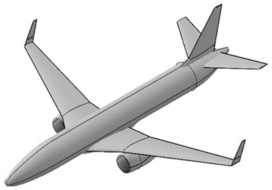





Input to Monte Carlo sim of 737-800

| Component | Cert point | Δ2 Offset | Δ2 Std Dev |
|---|---|---|---|
| Fan In Tone | Lateral | -6.08 | 4.05 |
| | Flyover | 0.16 | 2.21 |
| | Approach | -9.38 | 1.87 |
| Fan In BB | Lateral | -3.33 | 1.28 |
| | Flyover | -3.71 | 1.18 |
| | Approach | -3.49 | 3.85 |

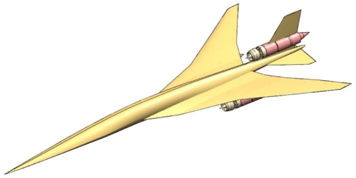
# Monte Carlo Inputs and Results



Conventional (737-800/CFM56-7B)

| Component | Cert point | Δ2 Offset | Δ2 Std Dev | Fract Weight |
|---|---|---|---|---|
| Jet | Lateral | **-0.01** | 0.69 | 0.84 |
| | Flyover | 1.74 | 0.63 | 0.50 |
| | Approach | 1.07 | 0.81 | 0.05 |
| Fan In Tone | Lateral | -6.08 | 4.05 | 0.02 |
| | Flyover | **0.16** | 2.21 | 0.18 |
| | Approach | **-9.38** | 1.87 | 0.01 |
| Fan In BB | Lateral | -3.33 | 1.28 | 0.00 |
| | Flyover | -3.71 | 1.18 | 0.00 |
| | Approach | -3.49 | 3.85 | 0.11 |

Cum std dev from ANOPP Benchmark: **1.5dB**



Supersonic (STCA 55t-U)

| Component | Cert point | Δ2 Offset | Δ2 Std Dev | Fract Weight |
|---|---|---|---|---|
| Jet | Lateral | **-1.68** | 3.85 | 0.90 |
| | Flyover | **-1.47** | 2.92 | 0.80 |
| | Approach | -1.61 | 1.71 | 0.20 |
| Fan In Tone | Lateral | 0.49 | 7.13 | 0.03 |
| | Flyover | 1.52 | 2.55 | 0.07 |
| | Approach | **0.30** | 9.46 | 0.30 |
| Fan In BB | Lateral | 1.48 | 4.71 | 0.00 |
| | Flyover | 0.28 | 3.96 | 0.00 |
| | Approach | -1.11 | 3.50 | 0.02 |

Cum std dev from ANOPP Benchmark: **7.8dB**

Monte Carlo model gives

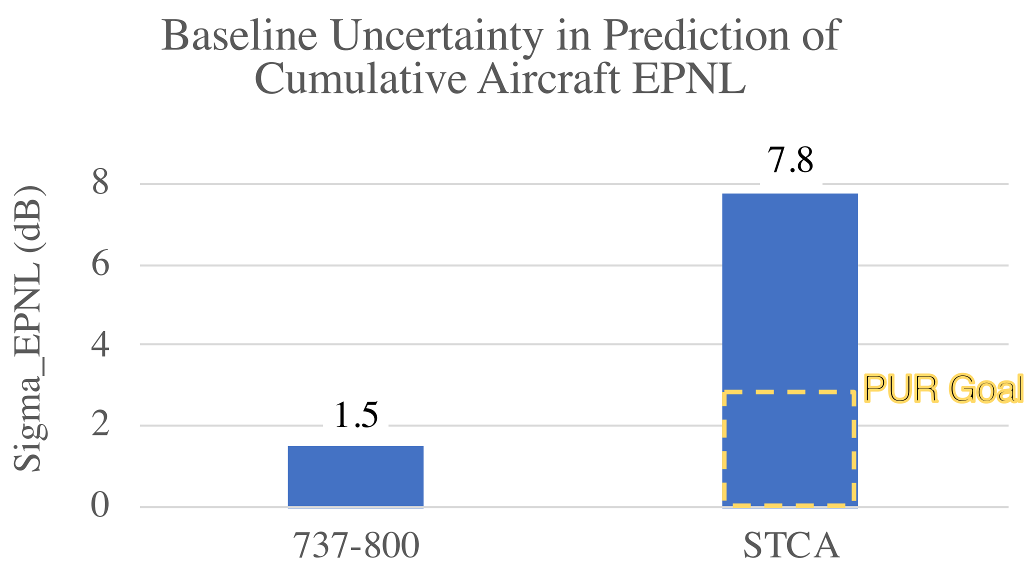
1) Relative weight of noise components at certification points
2) Uncertainty of predicting total aircraft EPNL

We're working the right components, and have lots of room for improvement!

# Baseline Uncertainty Assessment Summary

Results of Monte Carlo propagation of component uncertainties to total aircraft uncertainties.

These do not include uncertainties in translating scale-model rig test data to flight.




Progress Indicator metric defined, baselined for TC

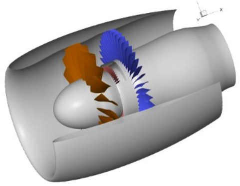
# Assessing uncertainty of physics-based simulation ‘data’

Fan noise validation re SDT and ADP tests

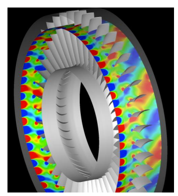
Miller, Envia, Stephenson, Svetkoff

- Incomplete: Recovering from computer hardware failure

Fan noise sources

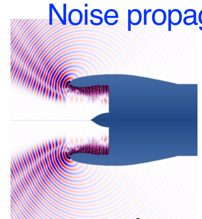


NASA SDT fan



Fine™/TURBO

Noise propagation



Actran™, COMSOL

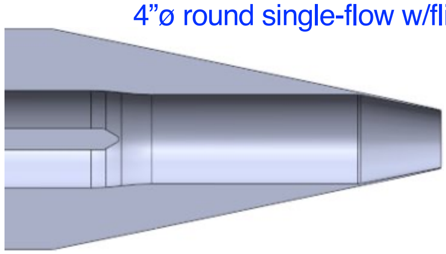
9x15 Source Diagnostic Test

Jet noise validation re GE N+2 baseline test (2011)

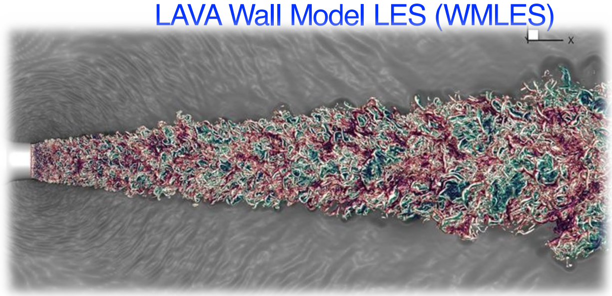
Stich, Housman, Ghate, Kiris

- 14 cases to be compared
- Static cases assessed; flight cases being completed

4”ø round single-flow w/flight



LAVA Wall Model LES (WMLES)



High-Flow Jet Rig in NATR

# Static Jet noise uncertainty assessment—WMLES vs Rig

Single round jet: acoustic Mach vs temperature matrix

Plots are PSD(Freq,Polar angle), colored by DPSD

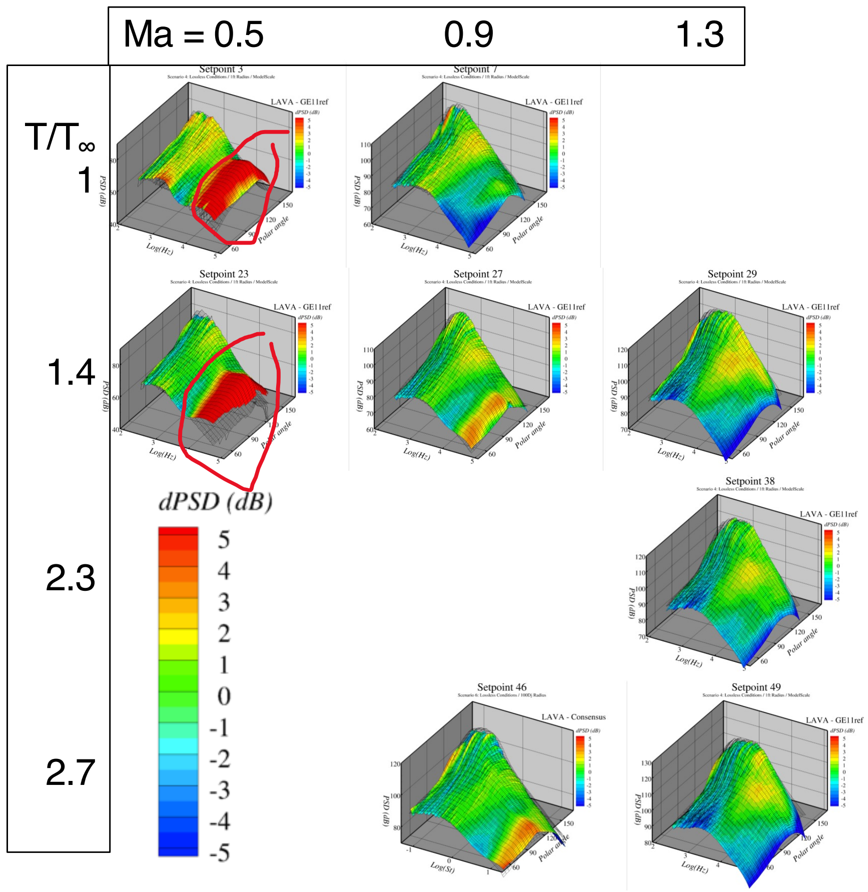
Observations:

- Lotsa green! (±1dB)
- Ma=0.5 (first column) has big discrepancy at high frequencies

Omitting Ma=0.5,

- average discrepancy in PSD is **-0.6 dB**
- std deviation in PSD is **1.8 dB**

- average discrepancy in EPNL is **0.4 EPNdB**
- std deviation in EPNL is **0.7 EPNdB**



# Static Jet noise uncertainty assessment—Rig vs rig

Compare between rigs:

- SHJAR (2”ø) vs NATR (4”ø)

Plots are PSD(Freq,Polar angle), colored by DPSD

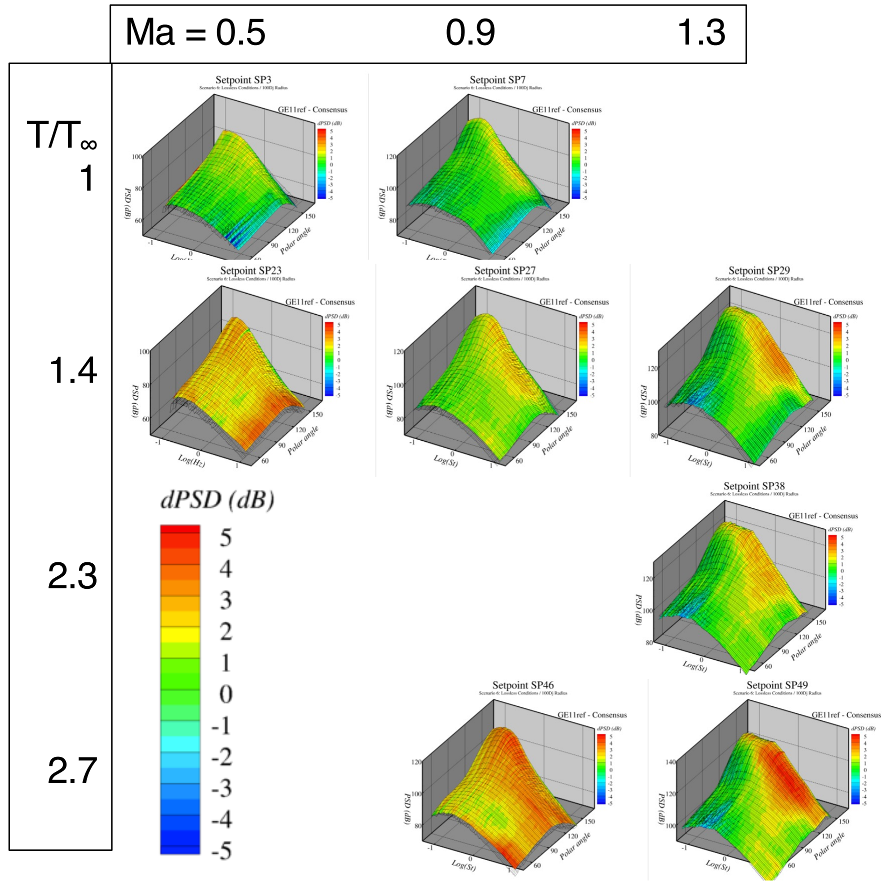
Observations:

- Aft angles, high frequencies have highest discrepancy

Including all setpoints

- average discrepancy in PSD is **0.8 dB**
- std deviation in PSD is **1.0 dB**

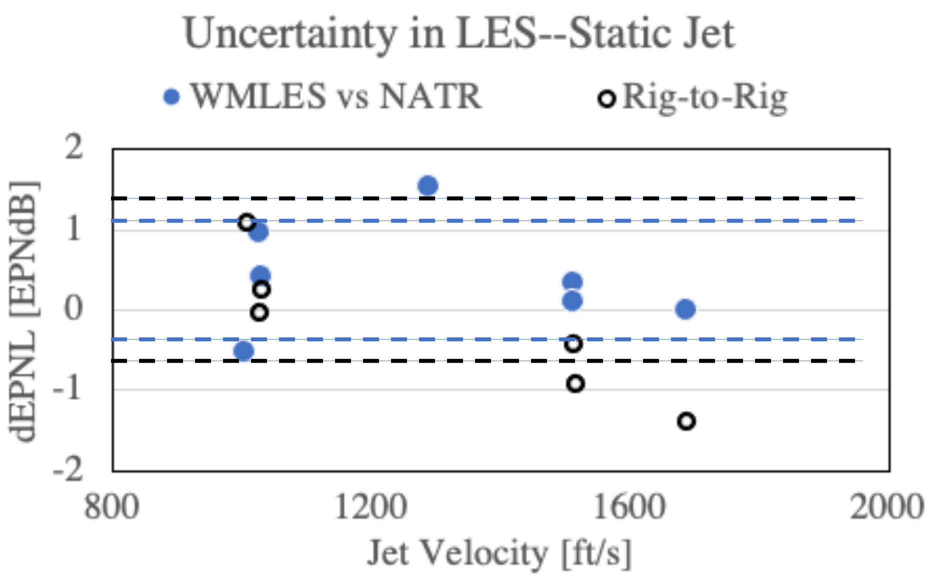
- average discrepancy in EPNL is **0.3 EPNdB**
- std deviation in EPNL is **1.0 EPNdB**



# Uncertainty of LES for jet noise (static cases)

Preliminary Results:

- Static cases, M > 0.5, only.
- Metric is EPNL of noise projected to LTO flight.
  - LAVA WMLES vs NATR rig data
- For static cases, WMLES uncertainty is comparable to rig-to-rig uncertainty



# Summary

The method of quantifying uncertainty of LTO noise for total aircraft using ANOPP was established for Prediction Uncertainty Reduction effort.

Method was used to obtain uncertainty in cumulative EPNL for conventional and near-term supersonic aircraft.

- Conventional aircraft: 1.5 EPNdB
- Supersonic aircraft: 7.8 EPNdB

Uncertainty of physics-based simulations is being assessed in similar manner.

- Fan toolchain in final stages of generating database
- Jet toolchain assessed for static cases (flight cases being finished now)

Jet LES database shows uncertainty only slightly larger than rig-to-rig uncertainty.

- Errors increase with decrease in jet speed; only flows Ma > 0.5 being considered.

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